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An Efficient Mechanism for Multicast Data Transmission in UMTS

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Abstract In this paper, we present an efficient scheme for the multicast transmission of the data in the Universal Mobile Telecommunications System (UMTS). We take advantage of the tree topology of the examined network and we introduce the use of Routing Lists (RLs) in the nodes of the UMTS. The adoption of these lists leads to the decrement of the transmitted packets and to the efficient use of network resources in the multicast transmission of the data. We describe in detail the appropriate steps for the successful multicast transfer of data. Furthermore, we analyze the handling of special cases such as user mobility scenarios. Especially, the various handover types are examined along with the Serving Radio Network Subsystem relocation procedure. Finally, we implement our approach in the NS-2 simulator and we present the performance of the multicast mechanism.

Keywords Multicast · UMTS · MBMS · Mobility management

1 Introduction

Third generation (3G) mobile networks are being deployed to provide enhanced voice and data services from anywhere and at anytime. Universal Mobile Telecommunications System (UMTS) constitutes the main standard of the third generation of wireless cellular networks. UMTS aims to provide high-speed data access along with real time voice calls. Wireless data

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is one of the major boosters of wireless communications and one of the main motivations of the next generation standards [1].

Multicast communications for wireline users have been deployed in the Internet for at least the past 10 years. The multicast transmission of real time multimedia data is a major issue in many current and future emerging Internet applications, such as videoconference, distance learning and video distribution. The multicast mechanism offers efficient multi-destination delivery, since data are transmitted in an optimal manner with minimal packet duplication [2].

Although UMTS networks offer high capacity, the expected demand will certainly overcome the available resources. Thus, multicast transmission over UMTS networks constitutes a challenge and an area of research. Actually, the adoption of multicast routing over mobile networks poses a different set of challenges in comparison with multicasting over the Internet. First of all, multicast receivers change their access point at any time. Second, mobile networks are generally based on a well-defined tree topology with the multicast receivers being located at the leaves of the network tree. The construction of a source-rooted shortest-path tree over such a topology is trivial and may be achieved by transmitting only a single packet over the paths that are shared by several multicast recipients. However, as a result of user mobility, there are several cases where this simplified view of the mobile network is violated [3,4].

Several mechanisms have been proposed to support multicast routing in UMTS. Additionally, the Multimedia Broadcast/Multicast Service (MBMS) framework of UMTS is currently being standardized by the 3rd Generation Partnership Project (3GPP) [5,6]. The limitation in these mechanisms is the lack of the analysis of the user mobility handling. Moreover, the Serving Radio Network Subsystem (SRNS) relocation procedure, a new mobility management mechanism in UMTS, is not examined. Our belief is that these issues are of major importance because mobility is the distinctive feature of the cellular networks and this is the motivation behind this study.

In this paper, we present an approach for the multicast transmission of the data in the UMTS. We take advantage of the tree topology of the examined network and we introduce the use of Routing Lists (RLs) in the nodes of the UMTS. The adoption of these lists leads to the decrement of the transmitted packets and to the efficient use of network resources. We describe in detail the necessary steps for the successful multicast transfer of the data. Furthermore, the various handover types are examined along with the SRNS relocation procedure. Finally, we implement our approach in the NS-2 simulator and present the performance of the multicast mechanism.

The paper is structured as follows: Sect. 2 provides an overview of UMTS in the packet-switched domain as well as the MBMS architecture. Section 3 is dedicated to the related work in the area of multicast data transmission in UMTS. In Sect. 4 we describe the proposed mechanism for the multicast transmission in UMTS analyzing in parallel the user mobility handling. Section 5 presents the simulation model, while Sect. 6 is dedicated to the experiments' results. Finally, some concluding remarks and planned next steps are briefly described.

2 Overview of UMTS and MBMS Architecture

UMTS network is split in two main domains: User Equipment (UE) domain and Public Land Mobile Network (PLMN) domain. UE domain consists of the equipment employed by the user to access the UMTS services. PLMN domain consists of two land-based infrastructures:

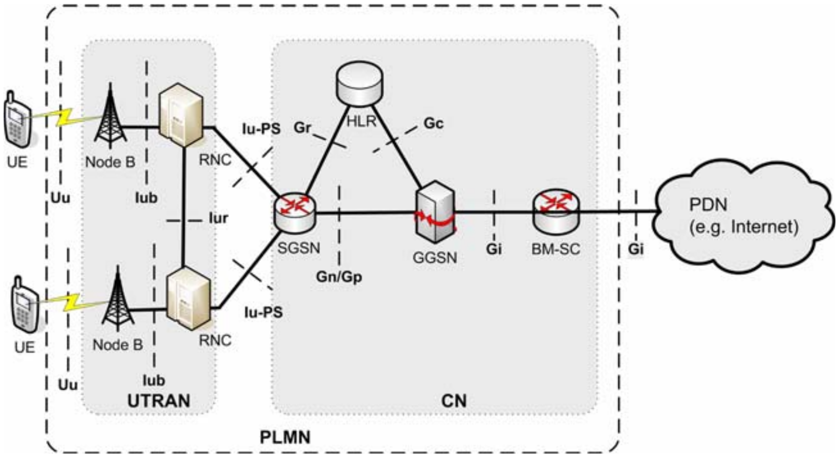


Fig. 1 UMTS and MBMS architecture

the Core Network (CN) and the UMTS Terrestrial Radio-Access Network (UTRAN) (Fig. 1). CN is responsible for switching/routing voice and data connections, while the UTRAN handles all radio-related functionalities. CN is logically divided into two service domains: the Circuit-Switched (CS) service domain and the Packet-Switched (PS) service domain [7]. CS domain handles the voice-related traffic, while the PS domain handles the packet transfer. In the remainder of this paper, we will focus on the UMTS packet-switching mechanism. The PS portion of the CN in UMTS consists of two kinds of General Packet Radio Service (GPRS) Support Nodes (GSNs), namely Gateway GSN (GGSN) and Serving GSN (SGSN) (Fig. 1). SGSN is the centerpiece of the PS domain. GGSN provides the interconnection of UMTS network (through the Broadcast Multicast–Service Center) with other Packet Data Networks (PDNs) like the Internet. UTRAN consists of two kinds of nodes: the first is the RNC and the second is the Node B. Node B constitutes the base station and provides radio coverage to one or more cells. Node B is connected to the User Equipment (UE) via the Uu interface and to the RNC via the Iub interface.

The 3rd Generation Partnership Project (3GPP) is currently standardizing the Multimedia Broadcast/Multicast Service (MBMS) [5,6]. As the term Multimedia Broadcast/Multicast Service indicates, there are two types of service mode: the broadcast and the multicast. Since the multicast mode is more complicated than the broadcast mode, it is more useful to present the operation of the MBMS multicast mode and the way that the mobile user receives the multicast data of a service. Actually, the reception of an MBMS multicast service is enabled by certain procedures. These are: Subscription, Service Announcement, Joining, Session Start, MBMS Notification, Data Transfer, Session Stop and Leaving (Fig. 2). The phases Subscription, Joining and Leaving are performed individually per user, while the other phases are performed per service. The sequence of the phases may be repeated, depending on the need of transferring data. Moreover, Subscription, Joining, Leaving, Service Announcement and MBMS Notification may run in parallel to other phases.

3 Related Work

Several multicast mechanisms for UMTS have been proposed in the literature. In [8], the authors discuss the use of commonly deployed IP multicast protocols in UMTS networks.

Fig. 2 Phases of MBMS multicast service provision

Three potential Internet multicast architectures are analyzed. The first is the existing multicast architecture that is standardized as an optional feature in the UMTS network. In this architecture the IP multicast routing protocol is terminated in the gateway between the Internet and the UMTS network. This solution requires few multicast aware UMTS nodes. However, this architecture does not provide any bandwidth savings in the UMTS network. The two other designs are Internet multicast architectures where the multicast functionality is pushed successively further out towards the UMTS terminal. These two architectures require multicast awareness from an increased number of UMTS network nodes. Higher complexity is introduced to achieve network resource savings. The presented multicast mechanism employs the Internet Group Management Protocol (IGMP) for group management and relies on the standard hierarchical tunneling of UMTS for distributing multicast packets to the group. The hierarchical tunneling mechanism of UMTS, however, does not lead itself to efficient multicast packet delivery, since each tunnel may only be established for a single subscriber. Considering a group of N multicast users, a single multicast packet must be duplicated and transmitted N times throughout the network in order to reach all the destinations. Depending on the distribution of the multicast users within the coverage area, this may lead to an inefficient usage of resources within the network.

A solution to the above described problem is presented in [4]. The authors, in order to overcome the one-to-one relationship between a single subscriber and a GPRS Tunneling Protocol (GTP) tunnel that is inherent to the hierarchical routing in UMTS, implement a Multicast-Packet Data Protocol (M-PDP) context for each multicast group in the GGSN and SGSN. An M-PDP context consists of a multicast group context (MGC) and n Multicast User Contexts (MUCs). An MGC stores parameters that apply to the whole group, such as the group address and QoS profiles. An MUC, on the other hand, maintains parameters for a single multicast user, with all MUCs within an M-PDP context accounting for the group members that are within the service area of a single node.

In [9], a multicast mechanism for circuit-switched GSM networks is outlined that only sends multicast messages to Location Areas (LAs) in which multicast users reside. This mechanism uses the existed UMTS/GSM short message architecture in order to perform multicast routing. In particular, two new tables are considered in the Home Location Register (HLR) and in the Visitor Location Register (VLR). The multicast table at the HLR records the Mobile Switching Centers (MSCs) that serve multicast users, while the VLR keeps track of the LAs that have multicast users. In the HLR, they implement a table MC_{H} that contains the addresses of the VLR's and the numbers of multicast members residing in the VLR's. In every VLR, they implement a table MC_V that contains the identities of the LA's and the number of the multicast members in these LA's. However, the multicast messages are delivered to all the cells of an LA, independently of whether or not multicast users are located in all cells. This is inefficient if an LA is large or only sparingly populated with multicast users.

Furthermore, in [10], a multicast mechanism for software upgrades in UMTS is described. In this approach, the authors use existing and well known IP multicast mechanisms to perform multicast group subscription and multicast routing in UMTS. For the multicast group subscription, they use IGMP, whereas for the multicast routing they propose the use of multicast routing protocols such as DVMRP (Distance Vector Multicast Routing Protocol), MOSFP (Multicast Open Shortest Path) and PIM (Protocol Independent Multicast).

4 Description of the Proposed Mechanism

In this section, we describe the proposed multicast packet forwarding mechanism with the use of Routing Lists (RLs). For simplicity, we consider that the functionality of the BM-SC is incorporated in the functionality of the GGSN (Fig. 1). Thus, in our analysis, only the GGSN node is used for the better understanding of the mechanism. In the following paragraphs, we describe the mechanism of multicast routing in UMTS, presenting the steps of message handling in each node of the network.

4.1 Packet Forwarding Mechanism

Our multicast mechanism introduces RLs in every node of the network apart from the UEs and the Node Bs. In the RL of a node, information is kept about which nodes of the lower level connect the current node with the UEs belonging to a specific multicast group. Consequently, there is one RL for each multicast group in each node (except for the UEs and the Node Bs). For example, consider the network topology illustrated in Fig. 3. Assume that UE1, UE2, UE11 and UE12 belong to multicast group MG1. GGSN preserves a RL for this multicast group which contains all the SGSNs which connect GGSN with the UEs belonging in MG1. These SGSNs are SGSN1 and SGSN2. Then, each SGSN preserves an RL with the RNCs which connect it with the UEs belonging in the examined multicast group. The RL of SGSN1 contains RNC1, the RL of SGSN2 contains RNC3 and RNC4, while RL of SGSN3 for MG1 is empty. The RLs of the RNCs are different from the RLs of the other nodes. In particular in the RL of each RNC that serves multicast users we keep pairs of UEs and their corresponding Node Bs. This means that the RL of RNC1 contains the pairs (UE1, Node B1) and (UE2, Node B2), the RL of RNC3 contains the pair (UE11, Node B8) and that of RNC4 contains the pair (UE12, Node B11). The rest RNCs have empty RLs.

The multicast routing mechanism is based on the RL processing in each node. If an incoming packet which is addressed to a multicast group, reaches a node, the corresponding RL

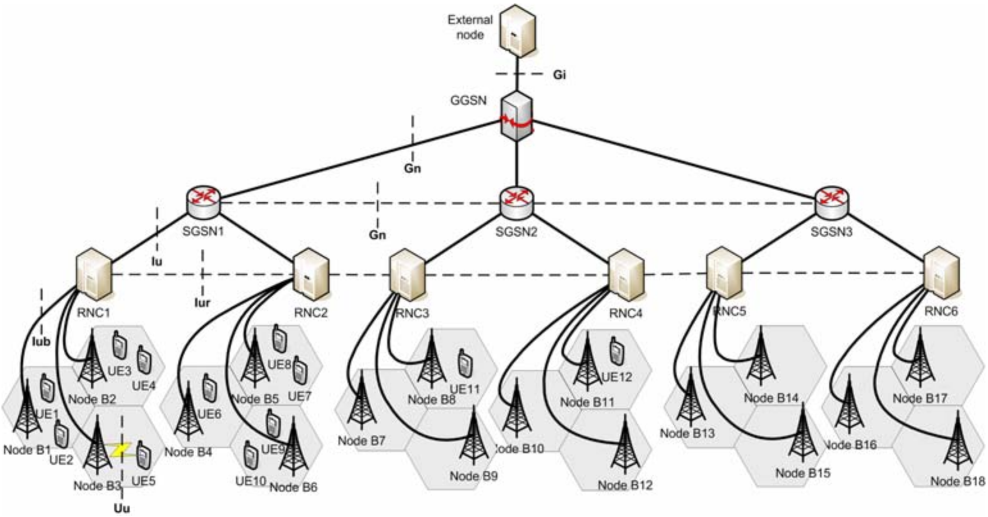
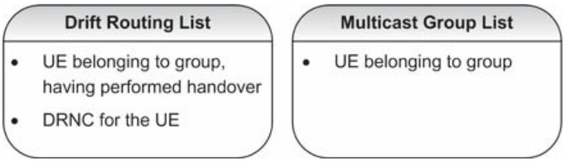


Fig. 3 Multicast packet transmission

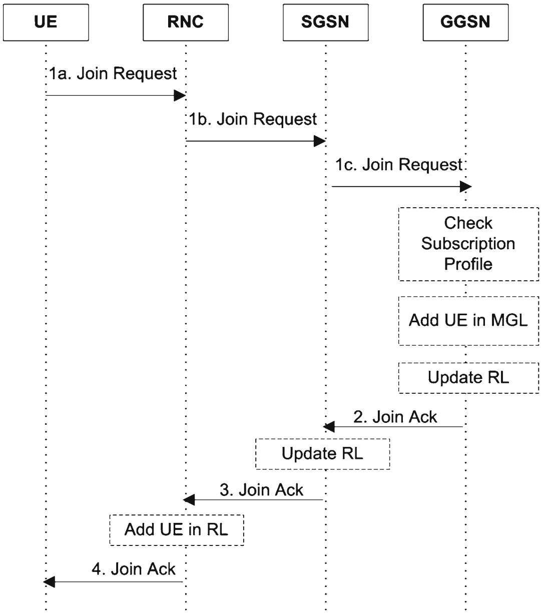
Fig. 4 Additional types of lists



is scanned. If RL is non-empty, the packet is duplicated and is transmitted once to each lower-level node existing in the RL. This procedure is repeated recursively in the lower-level nodes until each copy of the packet reaches its destination. For example, consider the case when incoming traffic for the previously defined multicast group MG1, reaches the examined PLMN (Fig. 3). Suppose that there is an incoming packet to GGSN and the packet addresses to MG1. GGSN checks the relevant RL. If this RL contains lower level nodes, the packet is forwarded once to each one of them. This packet forwarding is repeated recursively by the lower level nodes until the packets reaches the UEs belonging to the specific multicast group.

In this point we must mention the existence of two other kinds of lists. Additionally to the RLs, the Drift Routing Lists (DRLs) are used in the RNCs and the Multicast Group Lists (MGLs) in the GGSN (Fig. 4). The DRLs are lists which are used when inter-RNS handover has occurred. Each DRL corresponds to a multicast group and contains pairs of RNC-UE. These lists are useful for the multicast transmission over the Iur interface (Fig. 3) and will be thoroughly examined in a following section. Regarding MGLs, each list corresponds to a specific multicast group and maintains the UEs which belong to the group. These lists give the opportunity to the GGSN to retrieve the UEs belonging to a specific multicast group. Obviously, MGLs and RLs are not static elements but they are updated each time a UE joins or leaves a multicast group or when user mobility events transform the mobile network topology. Thus, for the correct transmission of the multicast data, it is essential that these lists are fully updated at every moment.

Fig. 5 Joining phase



4.2 Multicast Group Management

Consider a UMTS network providing an MBMS service. Suppose that a UE has completed the Subscription phase and wants to join a specific multicast group provided by the GGSN. In this case, the Service Announcement phase is executed. UE sends a message to the GGSN, requesting the list of available multicast groups. When the message reaches the GGSN, GGSN sends a reply message to the UE with the available multicast groups and the phase is terminated. Then, UE decides which multicast group(s) wants to join in. Figure 5 describe the steps of the multicast group(s) Joining phase. The Leaving phase is similar to the Joining phase.

4.3 User Mobility

In this section, we describe how our mechanism handles the user mobility in order to assure MBMS service continuity. We have to mention that the proposed handover mechanism is applicable only to DCHs and HS-DSCHs since FACH does not support handover at all. First we investigate the impacts of handover over the proposed mechanism and then we describe the adaptation of the mechanism to the SRNS relocation procedure.

Consider a UE that is a member of a multicast group and a MBMS multicast service provision that is in the Data Transfer phase. While the multicast packets are transmitted to the members of this multicast group, the specific UE changes cell. We examine the following three scenarios for this handover [11]:

1. *Inter-Node B/intra-RNS handover* The new cell belongs to another Node B and both Node Bs are in the same RNS.
2. *Inter-Node B/inter-RNS/intra-SGSN handover* The new cell belongs to another Node B which is in a different RNS and both RNSs are located under the same SGSN.

3. *Inter-Node B/inter-RNS/inter-SGSN handover* The new cell belongs to another Node B which is in a different RNS and both RNSs are located under different SGSNs.

In the first case, once the source RNC which is called Serving RNC (SRNC) decides to make an intra-RNS handover, it sends a radio link configuration prepare message to the Node Bs, as well as a radio resource control physical channel reconfiguration message to the UE. In the case of HS-DSCHs, the existing RL at the nodes of the network remain unchanged. All buffered PDUs for the user in the source cell are deleted and at the same time instance the MAC-hs in the new cell starts to request PDUs from the MAC-d in the service RNC [1]. In the case of DCHs, when a soft handover procedure is initiated, the UE in the new cell receives data from both the source and new Node Bs.

In the last two cases, the handling is identical. The basic concept of inter-RNS handover is that the handover is transparent to the SGSN(s). This is achieved with the use of the existing Iur interface. Thus, when inter-RNS handover takes place the data is transmitted through the Iur interface as it is shown in Fig. 7. In the proposed mechanism we use the DRLs in order to introduce multicast packet transmission over the Iur interface. This kind of transmission takes place when multiple handovers from the same source RNS to the same target RNS have occurred. Note that Iur interface does not exist in GSM networks.

The source RNC is called Serving RNC (SRNC) and the target RNC is called Drift RNC (DRNC). In case that subsequent handovers take place, multiple DRNCs are used. Only the SRNC has a connection to the CN for this session and the data reaches the DRNC via the Iur interface. In our mechanism we introduce multicast packet transmission over the Iur interface.

Figure 6 describes the steps of the inter-RNS handover procedure. The proposed mechanism is based on the existing handover procedure of UMTS but it incorporates some extensions in order to assure MBMS service continuity. These extensions are pointed out during the analysis.

Fig. 6 Inter-RNS handover procedure

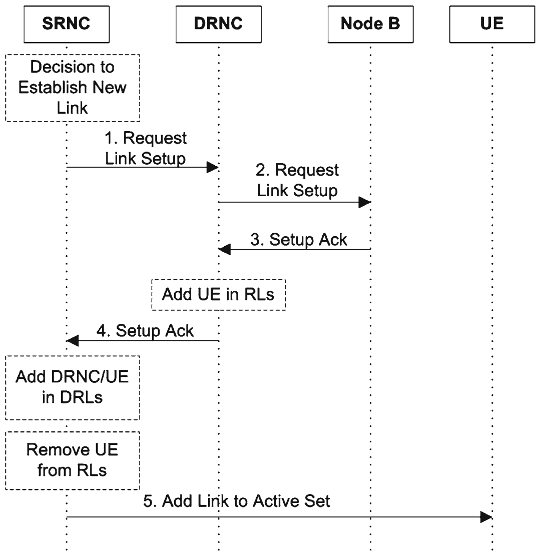
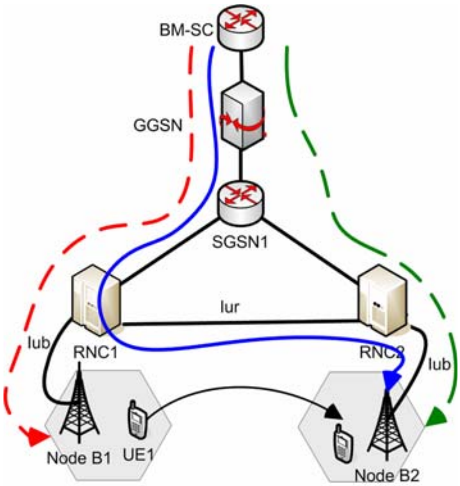


Fig. 7 Relocation procedure



1. The SRNC decides to make a handover based on the measurements from the UEs. An Iur connection is established between SRNC and DRNC and the SRNS requests radio link.
2. If radio resources are available, the DRNC forwards the request to the Node B in which the new cell belongs.
3. When the allocation of the radio resources is completed, the Node B sends an acknowledgement message to the DRNC and starts receiving uplink data from the UE. When the DRNC gets the acknowledgement, it adds the UE in the RLs related to the multicast groups that the UE belongs. Then, the DRNC forwards the acknowledgment to the SRNC.
4. When the SRNC gets the acknowledgment, it adds the UE/DRNC pair in the DRLs related with the multicast groups that the UE belongs in. Then, the UE is removed from the relevant RLs.
5. Finally, the UE is informed of the handover and receives the connection information.

Regarding the packet forwarding mechanism, an additional check must be made in the RNCs. The new functionality is related to the existence of the Iur connections and is based on the DRLs processing. Actually, in addition to the packet forwarding to the UEs, if a multicast packet reaches an RNC, the corresponding DRL is scanned. If DRL is non-empty, the packet is duplicated and is transmitted once to each DRNC existing in the DRL. These transmissions are made over the corresponding Iur interfaces and follow the multicast forwarding concept. If a UE has performed subsequent handovers, multiple DRNCs correspond to its connection. In this case, this procedure is repeated recursively in the DRNCs until the packet reaches the last DRNC. Finally, this DRNC will transmit the packet to the UE.

Having analyzed the MBMS handovers, we now proceed to the description of the SRNS relocation procedure according to the proposed mechanism. More specifically, the SRNS relocation procedure is applicable to UMTS networks and not to GSM ones. It is used to move the UTRAN to CN connection point from the SRNC to the DRNC (Fig. 7). If the DRNC is connected to the same SGSN as the SRNC, an intra-SGSN SRNS relocation procedure is performed. Otherwise, if the DRNC is connected to other SGSN, an inter-SGSN SRNS relocation procedure takes place.

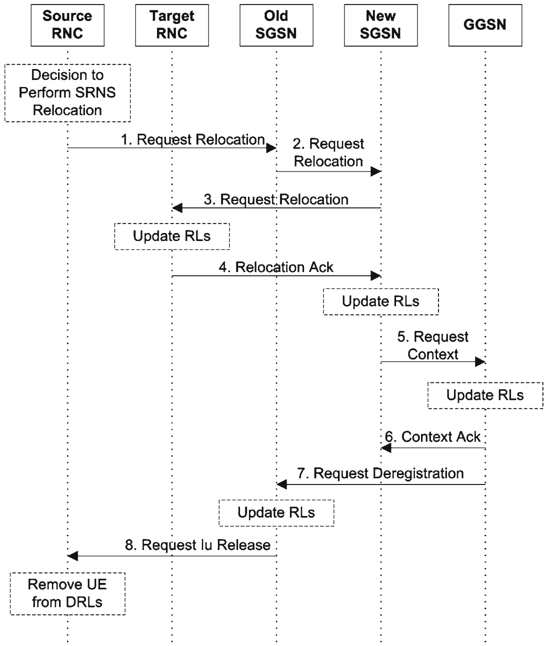


Fig. 8 Inter-SGSN SRNS relocation

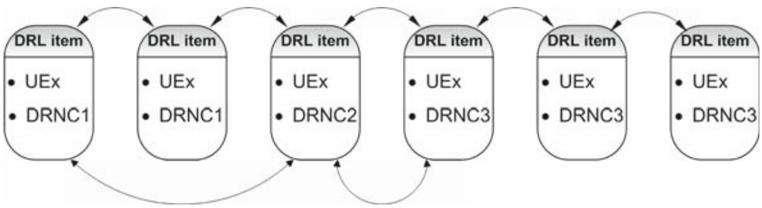


Fig. 9 Two-way linkage of the items in DRLs

Figure 8 illustrates the latter case which is the most general of the two. The case of intra-SGSN SRNS relocation is similar. All the steps are valid given the fact that both SRNC and DRNC are connected to the same SGSN.

5 Simulation Model

The proposed mechanism is implemented in the Network Simulator NS-2 [12] along with its EURANE extension [13]. Enhanced UMTS Radio Access Network Extensions (EURANE) for NS-2 is comprised of extensions for the support of UMTS network functionality.

Given the fact that the NS-2 simulator does not support the multicast transmission in UMTS, we implemented the multicast packet forwarding mechanism described above. First of all, we had to introduce the RLs in each node of the UMTS network except for the UEs. Every list that we created in the NS-2, is a double linked list which contains the appropriate methods in order to be accessed or modified (Fig. 9).

The next step of the implementation was to create the mechanism which fills these lists and to organize the whole procedure. For the communication of the nodes, as well as the

Table 1 Topology deployment and main radio channel aspects

Parameter	Value
Cellular layout	Hexagonal grid
Number of neighboring cells	18
Sectorization	3 sectors/cell
Site to site distance	1 Km
Cell radius	0.577 Km
Maximum BS Tx power	20 W (43 dBm)
Other BS Tx power	5 W (37 dBm)
Common channel power	1 W (30 dBm)
Propagation model	Okumura Hata
Multipath channel	Vehicular A (3 km/h)
Orthogonality factor	
(0 : perfect orthogonality)	0.5
E_b/N_0 target	5 dB
HS-DSCH Tx power (fixed power allocation mode - 35% of total Node B power is allocated to HSDPA)	7 W
FACH Tx power (95% cell coverage, TTI 80 ms, 1% BLER, 64 kbps MBMS service, no STTD)	7.6 W

transmission of the video we used RTP/RTCP messages. Since the RTP/RTCP protocols are not fully functional in the EURANE module, we modified them so as to support additional information such as the request type, the m_group_id and the QoS profile of the UEs.

In the simulation model, we consider the topology presented in Fig. 3 and for simplicity, we suppose that there are only two available multicast groups. More specifically, we consider that our network consists of three SGSNs, each SGSN serves two RNCs and each RNC serves three Node Bs. Since we do not want to create a symmetrical topology, we differentiate the number of the UEs located in each Node B. Thus, each one of Node B1, Node B2, Node B5 and Node B6 serves 2 UEs, and Node B3, Node B4, Node B8 and Node B11 serve 1 UE each (Fig. 3). The UEs of the network have already joined one of them. Assume that UE1, UE2 and UE3 have joined the multicast group 1 (MG1), and the remaining UEs have joined the multicast group 2 (MG2).

Additionally, in our simulation model we use several transport channels for the transmission of the data over the radio interface. In particular, in order to simulate the number of radio bearers established in the Iub interface as well as the data traffic in the Iub interface we consider transport channels such as High Speed-Downlink Shared Channels (HS-DSCH), Dedicated Channels (DCH), and Forward Access Channels (FACH).

The topology deployment as well as the main radio channel aspects that were used in the simulation is presented in Table 1. In particular, we consider a macro cell environment, which consists of 18 hexagonal grid cells. Regarding the power levels allocated to the three transport channels used in the simulation, we have to mention that 7 W of the available Node B's available power is allocated to the HS-DSCH and 7.6 W to the FACH [14–17].

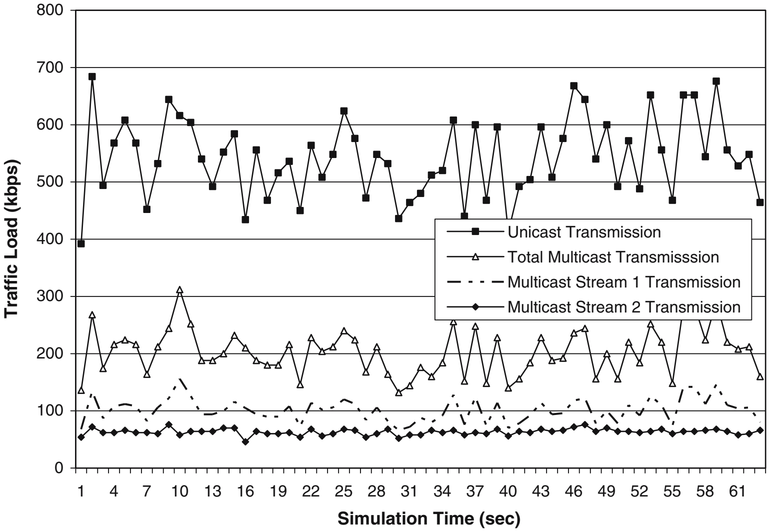


Fig. 10 Traffic load in the SGSN1-RNC1 link

As far as the video sequence is concerned, it is encoded to ITU-H.263 [18]. We use a video trace which was taken from [19] and we consider that there is an external node, connected to the GGSN. We assume that this external node is the media server which transmits the video traffic addressing to the multicast group. For the sake of simplicity, we consider that there is only one multicast group which the UEs of the network can join. For the transmission of the video data we use RTP traffic. This means that with the use of the RTCP reports, the GGSN has the opportunity to gain useful statistical information. The target bit rate of the video sequence is 64 kbps and the packet size is set to 512 bytes.

In the experiments, we focus on the Data Transfer phase that consists the main phase of the MBMS multicast service provision. Moreover, we examine several user mobility scenarios in order to cover all the cases. In the first case an inter Node B/inter-RNS/intra-SGSN handover takes place and a subsequent SRNS relocation is performed. Then, an SRNS relocation follows an inter-Node B/inter-RNS/inter-SGSN handover. Finally, we examine the case when multiple handover occurs from a Node B to another.

6 Results

First, we focus on the traffic load in order to evaluate the performance of the proposed mechanism. More specifically, we calculate the traffic load in the links of the UMTS network which uses the multicast scheme for the transmission of the video. Then, we compare it with the traffic load in the same link when multiple unicast is used. We use the network topology depicted in Fig. 3 measuring the traffic load over the link SGSN1-RNC1. The figure below illustrates the collected data.

As we can observe from Fig. 10, during the multicast transmission the traffic load in this link for every multicast stream is approximately the same with the theoretical video bit rate (64 kbps). Additionally, in the above figure we illustrate the total bit rate for the multicast transmission, which is by far lower from the bit rate of the unicast transmission. In fact, the same observation stands for every link of the network that has traffic. This occurs because in the multicast scheme, the packets are transmitted only once over each link of the network until they reach the mobile users. This procedure implies that the growth of the packets in the multicast transmission is by far less than the growth of the packets in the unicast transmission.

Another interesting statement comes from the comparison of the multicast and the unicast transmission of the video. In the figure above, we observe that the traffic load of the multiple unicast mechanism is by far bigger than the traffic load of the multicast mechanism. More specifically, in the unicast scheme the same packets are transmitted many times in every link which means that the traffic load increases. In the case of the multicast scheme, only one copy of each packet of each multicast group is transmitted over each link of the network and thus, the traffic load is limited to the theoretical video bit rate. Obviously, the use of multicast transmission can limit possible congestions compared to the multiple unicast transmission of the video.

In order to examine the service continuity during user mobility we simulate the following scenario. We suppose the previously described video traffic of 64 kbps which addresses to a multicast group and the MBMS service provision being in the Data Transfer phase. First, we assume that UE1 is located in the cell served by Node B1 (as depicted in Fig. 3) and it has already joined the multicast group. After 20 s of receiving data, UE1 performs a handover to the cell served by Node B4. This means that an inter-Node B/inter-RNS/intra-SGSN handover takes place. The packets are transmitted to UE1 through the Iur interface which connects the RNC1 and RNC2.

At 40 s, an SRNS relocation is requested from RNC1 and when the procedure is completed, the RNC2 is the new SRNC of the UE1 and the Iur is released for that session. At 60 s a new handover takes place for the UE1 from the cell served by the Node B4 to the cell served by the Node B7. This means that an inter-Node B/inter-RNS/inter-SGSN handover to the cell served by Node B7 occurred. Finally, a second SRNS relocation is requested. This request originates from RNC2 while the target RNC is RNC3. During the relocation procedure the Iur interface between RNC2 and RNC3 is released and the RNC3 is the SRNC of UE1. The simulation stops at 100 s. During this time, we calculate the bit rate of the data received by UE1. The results are presented in Fig. 11.

We can observe that the bit rate of the data received from UE1 is stable during the above described scenario. Thus, the service continuity is assured and the UE1 keeps receiving packets while moving across different RNSs and being served by Iur interfaces. This fact also results from the simulation log which shows that no packet loss takes place during the procedure.

The next aspect which we examine is the multicast transmission of video over the Iur interface. We suppose that multiple handovers take place from the same source RNC to the same target RNC. We consider the network topology depicted in Fig. 3 and we assume that four UEs are located in the RNS controlled by RNC1 (let them be UE1, UE2, UE3 and UE4). These UEs are members of a multicast group and the MBMS service provision for that group is in the Data Transfer phase. During this simulation four subsequent inter-RNS handovers take place at 20, 40, 60 and 80 s, respectively. We suppose that the new cells are located in the RNS controlled by RNC2 and that the handovers are not followed by relocations. The simulation is terminated at 100 s. In this case, we calculate the traffic load in the Iur interface connecting the RNC1 with RNC2. Then, we compare the results with the traffic load in the same link when multiple unicast is used. Figure 12 displays the outcome.

Figure 12 depicts clearly that the proposed multicast scheme uses efficiently the Iur interface. In fact, the traffic load remains stable without depending on the number of handovers.

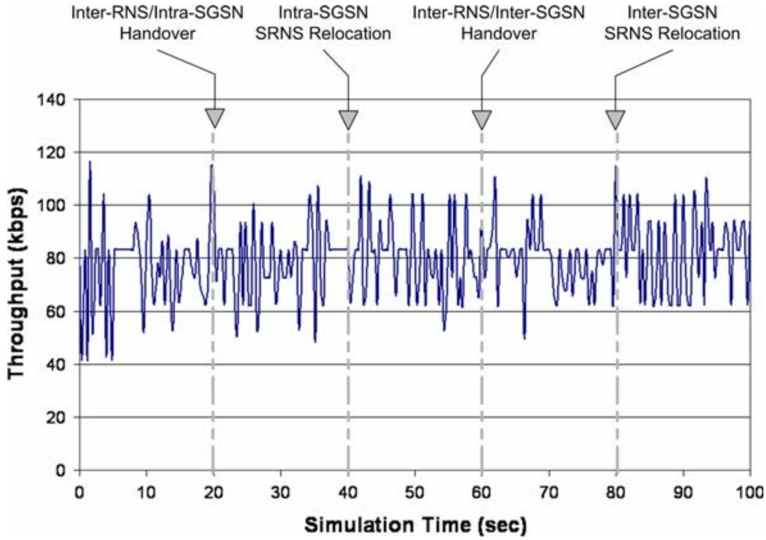
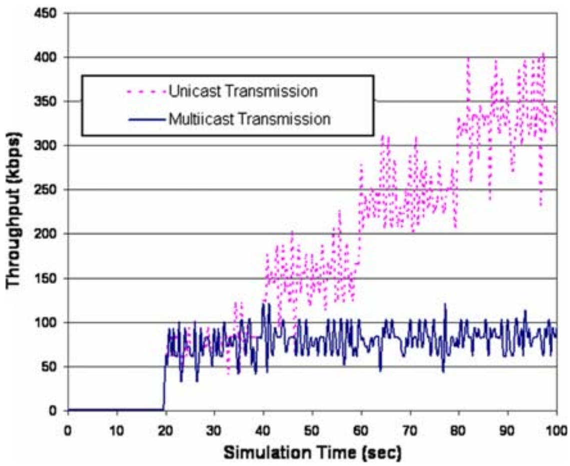


Fig. 11 Bit rate received during user mobility scenario

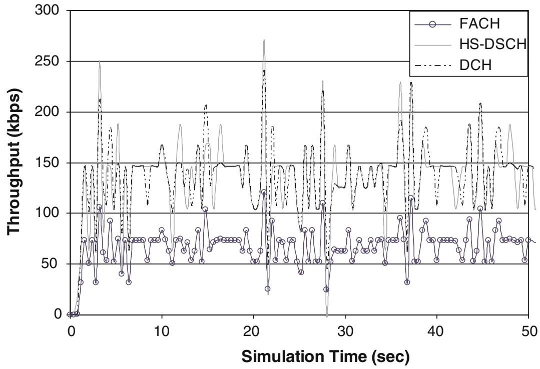
Fig. 12 Traffic load over the Iur interface



On the contrary, the existing multiple unicast mechanism causes increment of the transmitted load, making this interface a potential bottleneck.

In order to simulate the number of radio bearers established in the Iub interface as well as the data traffic in the Iub interface we consider different transport channels for the transmission of the multicast data over the Iub and Uu interfaces. In particular we use transport channels such as HS-DSCH, DCH, and FACH. In general, in case we use the FACH as transport channel each multicast packet send once over the Iub interface and then the packet is transmitted to the UEs that served by the corresponding Node B. In case we use DCHs for the transmission of the multicast packets, each packet is replicated over the Iub as many times as the number of multicast users that the corresponding Node B serves. Finally, with HSDPA, the resources can be shared between all users in a particular sector. The primary channel multiplexing occurs in the time domain, where each UE listens in a particular TTI. Regarding the

Fig. 13 Traffic load in the Iub (RNC1 – Node B1)



resources in the Iub, a separate timeslot must be used to transport the multicast data to each multicast receiver. However, one could envision that all multicast receivers could receive the same timeslot that contains the multicast data, but in its current form the HS-DSCH has not been modified to allow this. Thus, the number of time slots required for the transmission of the multicast data to the multicast users is equal to the number of multicast users reside in the corresponding cell.

The above remarks are shown in Fig. 13, where we measure the traffic load in the Iub interface that connects the RNC1 and the Node B1 (Fig. 3). Due to the fact there are two multicast users located in the cell served by the Node B1 (Fig. 3) the total traffic load in the corresponding Iub if we use DCHs or HS-DSCHs is twice as large as the traffic load if we use FACH as transport channel.

7 Future Work

The step that follows this work could be the study of an MBMS handover mechanism in RNC in order to optimize the transmission of the multicast data in the Iub interface. Additionally, an innovative algorithm could be developed which would choose the most efficient transport channel for the transmission of the multicast packets depending on the distribution of the users and the network topology at any given time. In this way, interesting issues must be taken into account such as the user mobility, the max number of users that a channel can service as well as power issues. Additionally, we want to enhance the implementation of the proposed mechanism so as to keep track of various parameters.

8 Conclusions

In this paper, we proposed a multicast scheme for UMTS. The Routing Lists were introduced in each node of the network except the UEs and the Node Bs. In these lists we record the nodes of the next level that the messages for every multicast group should be forwarded. Moreover, the Drift Routing Lists (DRLs) were added. These lists contain information relevant to handovers performed and their processing leads to multicast transmission of data between RNCs. As we showed, RLs and DRLs lead to the decrement of the transmitted packets and the more efficient use of the network resources in the multicast routing in UMTS. Minor modification in the UMTS architecture and the mobility management mechanism is needed.

We analyzed the exact steps that are essential for a successful MBMS multicast service provision, continuity and efficiency. Furthermore, we implemented the proposed mechanism in NS-2 network simulator. Since the Data Transfer phase is the most important phase in the multicast service, the experiments were focused in the transmission of the multicast data. Our simulation results show that the proposed mechanism for the multicast packet forwarding in UMTS works correctly and performs efficiently.

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